Intelligent Transportation Systems and Sustainable Communities
Findings of a National Study

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The 1990s may well be remembered as the decade in which the idea of sustainability took hold in government, business, academia, and popular culture. In the United States, concerns with sustainability have entered policy discussions at various levels of government and sectors of the economy. The application of the sustainability paradigm to transportation has coincided with the advent of intelligent transportation systems (ITS). ITS—the application of advanced technologies (e.g., computers, communications, advanced sensors) to the surface transportation system—is a major new advanced transportation technology initiative that has become a highly touted prospect for improving the nation's surface transportation system. ITS could have significant effects on the nation's environment, economy, and society, and this has prompted widespread research and speculation on the range of potential ITS impacts. It has also brought ITS into the sustainability debate, and controversy exists over whether ITS will facilitate or undermine efforts to promote sustainable communities. A series of conceptual and applied exercises being done at the national level, as well as within Minnesota, on the implications of the sustainability paradigm on ITS are described. After the policy context surrounding ITS is introduced, key dimensions of the sustainability concept, particularly sustainable development and sustainable communities, are examined. The concept of sustainable communities is linked to transportation and ITS. In conclusion, findings on how ITS and other information technologies might promote sustainable communities are given, with special attention to the context of Minnesota's ITS program.

The 1990s may well be remembered as the decade in which the idea of "sustainability" first took hold in government, business, academia, and popular culture. The most heralded expression of sustainability—sustainable development—occurred at the 1992 Earth Summit, where representatives from more than 150 nations, including 117 presidents and prime ministers, pledged to integrate environmental and economic development in their respective nations' planning and policy. Defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (*1*), sustainable development has become an increasingly common standard for measuring human progress (*2*).

In the United States, concerns about sustainability or sustainable development have entered policy discussions at various levels of government and sectors of society. Important sustainable development projects exist at the national level, (e.g., President's Commission on Sustainable Development), the state level (e.g., Minnesota Sustainable Development Initiative), and the local level (e.g., Sustainable Seattle). Similar efforts to incorporate sustainability concepts are now under way in the transportation sector. For example, TRB is conducting a major study on the concept of sustainable transportation. Other efforts to link transportation and sustainability include a White House–sponsored dialogue on greenhouse gas emissions from personal automobiles (called "Car Talk") and ITE's adoption of "Transportation and Sustainable Communities" as the theme of its 1997 conference. All of these initiatives will have important effects on the design of future transportation systems.

Efforts to apply the sustainability paradigm to transportation have coincided with the advent of Intelligent Transportation Systems (ITS). ITS—the application of advanced technologies (e.g., computers, communications, advanced sensors) to the surface transportation system—is a major new advanced transportation technology initiative and a highly touted prospect for improving the nation's transportation system. ITS could have significant effects on the nation's environment, economy, and society, and this has prompted widespread research and speculation on the range of potential ITS impacts. It has also brought ITS into the sustainability debate, and controversy exists over whether ITS will facilitate or undermine efforts to promote sustainable communities. Replogle (*3*), for example, argues that an ITS program stressing demand management strategies could "be the most important enabling technology driver in decades to reform and progress in American transportation, winning for our citizens sustainable high wage jobs, reduced traffic delay, more livable communities, and a healthy environment." Cervero (*4*), however, expresses far less optimism about the potential contribution of ITS to sustainable communities, arguing that a major ITS deployment program "stands to worsen by orders of magnitude" the problems of excessive automobile travel, suburban sprawl, and air pollution.

The authors argue that ITS technologies can indeed promote efforts to build sustainable communities. By providing vast amounts of information on the performance of the transportation system, ITS could allow for greater operational control of that system and reduce the negative externalities associated with transportation. Easily disseminated information about the transportation system—such as price signals that convey the true costs of driving, "real-time" traffic and emissions data, or information on the costs and benefits of alternative transportation policies—will enable transportation to serve the multiple economic, social, and environmental goals implied by the sustainable communities paradigm. ITS offers the prospect of an information-intensive transportation system, in which the information provided could increase mobility, reduce environmental damage, and better serve the interests of communities. Such a system will not evolve automatically, however. Before the promise of ITS becomes a reality, ITS deployments must be integrated into an overarching policy and institutional framework aimed at promoting sustainable communities.

This paper is part of an ongoing series of conceptual and applied exercises being done at the national level, as well as within Minnesota,

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on the implications of the sustainability paradigm for ITS. Part of this study focuses on providing the Minnesota Department of Transportation with recommendations on how ITS might promote sustainable communities in Minnesota. After a brief introduction to the policy context surrounding transportation and ITS, the authors examine key dimensions of the sustainability concept, particularly sustainable development and sustainable communities. Then the concept of sustainable communities is linked to transportation and ITS, exploring three specific areas—air quality, land use, and social equity—that are central to the ITS/sustainability debate. Finally comes a discussion of policy implications and specific recommendations for how ITS can promote sustainable communities, with special reference to Minnesota's ITS program.

BACKGROUND

American transportation planning has been premised on the notion that travel services must keep pace with increases in the number of people, vehicles, and desired trips. Planning has been reactive, for the most part, attempting to increase or maintain mobility and travel safety in the face of rapid population growth. Whatever social ills have been caused by the development of massive public and private transportation systems, the alternative of limiting mobility has been judged far less desirable.

The policy emphasis on mobility has in part resulted in vehicle miles traveled (VMT) rising much faster than population. Between 1970 and 1990, the United States experienced a 21.3 percent population increase, a 78 percent rise in vehicle registrations, and a 91.6 percent increase in VMT (*5*). The surface transportation infrastructure has been unable to accommodate this dramatic increase, as highway capital outlays across the nation decreased over this same period (*6*). The result has been chronic traffic congestion in most urban areas, causing annual congestion-related productivity losses estimated between $43 billion and $100 billion (*7*).

Furthermore, despite significant improvements in fuel efficiency and pollution reduction technologies such as catalytic converters, the transportation sector continues to damage human health and cause enormous environmental damage. Air pollution from automobile emissions increases the incidence of heart and lung disease, and the Environmental Protection Agency (*8*) estimates that 56 percent of the cancer risk associated with air pollution results from motor vehicle emissions. In addition to causing regional air pollution, motor vehicle emissions and the transportation infrastructure also damage ecosystems and deplete natural resources. There may be global impacts as well, as the transportation sector is responsible for roughly 30 percent of global greenhouse gas emissions, which may contribute to global warming (*9*). In all, estimates of the external costs of the U.S. transportation system (measured in the costs associated with damage to human health, damage to agriculture, and extinction of plants and animals) range from $10 billion to $200 billion/year (*10*). Concerns over these externalities are the impetus for efforts to create a more sustainable transportation system.

ELEMENTS OF SUSTAINABILITY

Sustainable Development

Before describing possible links between ITS and sustainable communities, it is necessary to define sustainable development. Since the World Commission on Environment and Development's (WCED's) 1987 definition of sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs," more than 70 definitions of sustainable development have entered the policy literature (*11*). Despite its promise as a measure of progress and as a mobilizing vision, the concept of sustainable development remains controversial and difficult to define; it is particularly difficult to translate into practical action. Indeed, Ruttan (*12*) correctly notes that the popularity of the WCED definition stems in part from its being "so broad that it is almost devoid of operational significance." Take the notion of ecological sustainability with respect to a lake, for example. Sustaining a healthy lake as a stable aquatic ecosystem means reversing the natural process of eutrophication that slowly turns lakes into marshes, and marshes into forests. In such instances, it is ecological integrity that must be sustained, not necessarily a particular ecosystem.

Despite their limitations, sustainability concepts provide useful frameworks for thinking about the future. Given that almost 200 international conferences, professional meetings, and scientific associations have used sustainability as the theme of their gatherings in recent years (*2*), it is not surprising that the transportation community is now talking about sustainability.

Sustainable Communities

Using the WCED's definition of sustainable development, the authors offer the following as a synthetic definition of the various strands considered under the rubric of sustainable communities (*2*):

> Sustainable communities have levels of pollution, consumption, and population size that are in keeping with regional carrying capacity; their members share an ethic of responsibility to each other and to future generations; their goods and services reflect the full social and environmental costs of their provision; their system of governance and civic leadership encourages democratic deliberation; and their design of markets, transport, land use, and architecture enhances neighborhood livability and environmental quality.

As highlighted in Figure 1, sustainable communities consist of three basic interrelationships: (*a*) the psychological and physical relationships between the quality of human life and the quality of the natural environment (the biosphere); (*b*) the social and political relationships between the quality of individual human life and the quality of community engagement and collective self-governance, and (*c*) the local-global relationship between community planning and governance and the health of the planet. Sustainable communities, in the authors' view, are made possible by this set of forces operating in a mutually enhancing fashion.

Communities represent the social and physical expression of interdependence. Although they can be organized for both good and ill ends, communities connect individuals with each other, and collectively with the bioregion that envelops them. When designed to promote cooperation for mutual benefit, they provide what Putnam (*13*) calls "virtuous circles" or self-reinforcing stocks of "social capital: [which includes] cooperation, trust, reciprocity, civic engagement, and collective well-being." Communities do for people what ecosystems do for the rest of nature: they bring a measure of stability and common purpose to the lives of individual organisms.

Another key element of sustainable communities is concern for ecological carrying capacity, which depends on at least three key factors: the assimilative capacity of ecosystems and bioregions (e.g.,

Quality of Human Life	*health, freedom, dignity, access to resources, fulfillment of individual potential*
Civic Engagement	*sense of place, participation in governance, social equity*
Quality of Biosphere	*biological diversity, carrying capacity, life support, renewable resource base*

FIGURE 1 Model of sustainable community (*2*).

the ability of marshes to absorb and break down certain harmful pollutants), the regenerative capacity of natural systems (e.g., forest regrowth after fires), and the technological expansion or substitution effect, whereby manmade artifacts can be used in place of damaged natural amenities (e.g., growing food hydroponically in order to cope with topsoil erosion). Physical indicators such as emission levels of CO, CO_2, the level of paved surface area, and so forth can suggest the threshold level for sustainability (*2*). Perhaps more than anything else, it is concerns about the earth's carrying capacity that spur investigation into the concept of sustainable transportation.

Sustainable Transportation and ITS

Besides sustainable development and sustainable communities, "sustainable transportation" forms a third conceptually important link between ITS and sustainable communities. And defining sustainable transportation, in turn, begins with the understanding that transportation is a complex system that integrates people, modes, and land uses. Despite widespread understanding of such system attributes, most conceptual approaches to transportation still reflect separate modes (i.e., driving as separate from bicycling, transit, or walking). Acknowledging the system attributes of transportation, and building on the definition of sustainable communities provided earlier, the authors define sustainable transportation as

> Transportation services that reflect the full social and environmental costs of their provision; that respect carrying capacity; and that balance the needs for mobility and safety with the needs for access, environmental quality, and neighborhood livability.

Figure 2 provides a systems framework for linking the concept of sustainable communities with transportation and ITS. It lists the three components of sustainable communities discussed before—quality of life, civic engagement, and quality of the biosphere—and suggests indicators for each component. It then highlights three areas where sustainable communities and transportation intersect; emissions, land use, and travel behavior. Finally, the chart gives particular ITS applications and specific venues for their implementation.

The link between ITS and sustainable communities stems from the ability of ITS to create a transportation system rich in information, or what might be called an information-intensive transportation system. An information-intensive transportation system promotes sustainable communities in two ways. First, it substitutes information for new lanes, roads, and highways as a way of increasing the capacity of the transportation system. In doing so, ITS substitutes "information for stuff" (*14*); in this case, the "stuff" being replaced with information is the material resources necessary to build roads. In addition to using fewer resources, substituting better information for new roads may also conserve open space, decrease the noise and community disruption related to new highways, and reduce the damage to biodiversity. ITS thus supports a fundamental tenet of sustainability: that the earth's resource base has limits, that some of those limits are being approached, and therefore sustainable development depends on accommodating economic growth while consuming fewer resources.

The second way in which ITS can promote sustainable communities is by enhancing the performance of the transportation system, with *enhanced performance* defined broadly to include reducing the system's negative externalities. Once again, information plays the

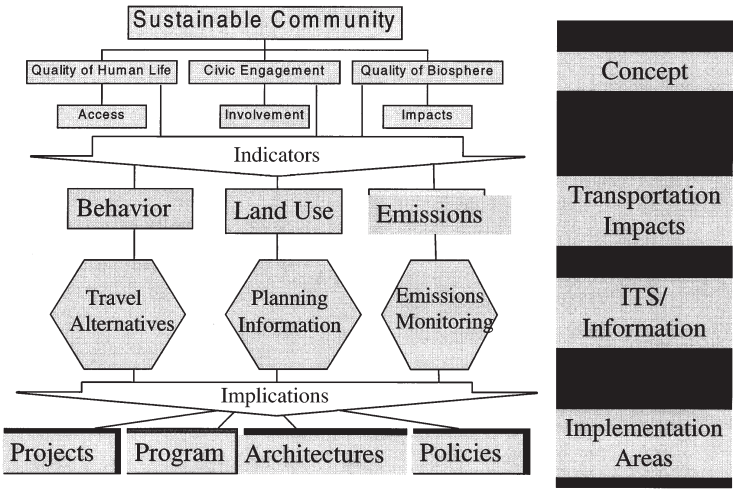

FIGURE 2 Sustainable communities and ITS.

key role, for the information-rich environment provided by ITS allows for greater operational control of the transportation system. With more control of the system, it becomes easier to direct it toward specific purposes, such as serving broad social, economic, and environmental goals. Table 1 presents how various ITS applications channel information to drivers, traffic managers, and other transportation system stakeholders in ways that promote sustainable communities. For example, ITS applications such as remote sensing can generate emissions data and assist air quality officials in targeting gross polluters. Another example is congestion pricing, or charging drivers a fee that varies with the level of traffic on a roadway. Congestion pricing conveys information (in the form of price signals) that alerts drivers to the overall social and environmental costs of driving, making them aware that driving imposes external costs while encouraging travel behavior that causes less environmental damage.

ITS and other information technologies thus hold great promise for efforts to make the transportation system more compatible with sustainable communities. As discussed earlier, however, this promise can be realized only if ITS investments are part of a comprehensive strategy aimed at integrating broad social, environmental, and economic goals. And while the National ITS Program lists environmental quality as one of its primary goals, it appears that, at least during the first 3 years of the program, this goal was a relatively low federal priority. This assertion is based on a review of federal ITS activities conducted by the Congressional Budget Office (CBO) (*15*). According to the CBO report, only $5.6 million—totaling 1.2 percent of federal ITS funds obligated through 1994—was spent on projects in which environmental concerns were the primary motive. This compares with $304.6 million (65.3 percent of federal funding obligated through 1994) spent on travel and traffic management projects. These data led the CBO to conclude that

> Among the objectives [for the ITS program] set by the Congress, the one that seems to have received the least attention is the environment. Although some of the travel management projects could benefit the

TABLE 1 ITS-generated information and sustainability

ITS Category	*Application*	*Flow of Information*	*Contribution to Sustainability*
Traffic Management	*--Traffic signal synchronization*	--traffic information to traffic mangers allows re-timing of signals to optimize traffic flow	--reduces energy usage and emissions related to "stop & go" traffic and congestion
	--Incident detection	--incident (i.e. freeway accident) information to traffic managers allows faster emergency response, re-timing of ramp meters, etc.	--reduces energy usage and congestion-related emissions
Traveler Information	*--Pre-trip traveler information*	--traffic information to traveler allows for shift in travel time, route, or mode	--reduces energy usage, congestion-related emissions and/or the # of trips/ SOVs
	--En-route traveler information	--traffic information to driver allows shift in route	--reduces energy usage congestion-related emissions
Other	*--Congestion-sensitive road tolls (i.e. congestion pricing)*	--information to drivers (in the form of price signals) that relays full social and environmental costs of driving	--reduces energy usage and emissions by reducing # of trips/SOVs, reducing congestion, and perhaps encouraging less auto-dependent land use patterns (i.e. less sprawl)
	--Remote sensing of emissions	--vehicle emissions information to drivers and/or air quality managers	--aid in targeting 'gross polluters' (10% of vehicles responsible for roughly 50% of emissions)
	--Demand-responsive transit services	--information to transit managers and transit riders on supply/demand/status related to transit	--reduces emissions and energy usage by encouraging use of transit; helps create more equitable distribution of transportation services to underserved populations (i.e. handicapped, elderly)

environment, how they might do so is not entirely clear because short-term reductions in traffic and congestion could lead to greater numbers of vehicles on the road, resulting in even greater pollution.

The CBO report rightly points out that funding for ITS projects does not necessarily represent a zero-sum game between promoting environmental goals or mobility goals. However, many in the environmental community, wary that ITS investments that increase the carrying capacity of the transportation system will ultimately worsen pollution by encouraging more driving, believe the ITS program may be heading in the wrong direction (*3*,*4*).

DISCUSSION OF RESULTS

Integrating transportation policy with efforts to reduce air pollution, manage land use patterns, and promote social equity applies the essence of the sustainability framework. ITS systems, by providing information on the performance of the transportation system, provide a technological means of moving toward the sustainability ideal. But this promise cannot be realized without a transportation policy framework that goes beyond the traditional emphasis on mobility and traffic efficiency. Crucial to the creation of a sustainable transportation system is a transportation policy guided by a vision of sustainable communities.

Such a vision was behind major transportation legislation passed in 1991, the Intermodal Surface Transportation Efficiency Act (ISTEA). ISTEA marked a watershed in the evolution of U.S. transportation policy, shifting the focus from massive highway construction projects to facilitate economic growth and urban development. The law instructs transportation planners to analyze "the overall social, economic, energy, and environmental effects of transportation" [C.F.R. 450.316(a)(13)]. In conjunction with the 1990 Clean Air Act Amendments, ISTEA further integrates transportation policy with efforts to control air pollution and manage land use patterns. ISTEA also mandates that the benefits of the transportation system be extended to poor and minority communities and others "traditionally under-served by the transportation system" [C.F.R. 450.316(b)]. Camph (*16*) characterizes the new program and policy directions in ISTEA as follows:

- *Emphasis on a systems approach*, with increased focus on alternative modes, environmental protection, and mobility of persons and goods;
- *A holistic approach to planning*, which expands concepts of system performance to include mobility and access, equity, reliability, and external impacts and stipulates a cooperative partnership for planning between local and state governments;
- *Flexibility*, unprecedented flexibility in moving money between modes (roads, transit, bikes, and pedestrians), making funding decisions clearly a part of the planning process;
- *Linkage to air quality and environment*, in both funding and planning;
- *Emphasis on performance*, with a focus on preservation, maintenance, and management of the existing roads and highways through management systems;
- *Emphasis on aesthetics*, with both planning requirements and funding set-asides for scenic byways and easements, historic preservation, and other features;
- *Focus on safety*, on the roads and in communities, for users and nonusers;
- *Emphasis on public involvement*, which moves the nation toward a participatory model of decision making, with an informed citizenry playing a key role.

ISTEA has thus made regional transportation planning a more comprehensive, participatory process, and one in which planners increasingly are required to balance the goal of traffic efficiency with broad social and environmental concerns. This process differs significantly from traditional transportation planning, when policy makers had "few incentives to include urban renewal, social regeneration, and broader transportation objectives in their programming" (*17*). ITS provides a new set of tools to implement the holistic vision of transportation policy embodied in ISTEA, but it is critical that these tools be directed properly, as the authors believe that ITS systems per se are neither all "good" or all "bad" in relation to sustainable communities: what matters is that they be integrated into a policy and institutional framework aimed at achieving this vision.

PRELIMINARY FINDINGS AND RECOMMENDATIONS

It has been argued that ITS technologies can assist efforts to build sustainable communities. To do this, the ability of ITS to produce transportation-related information must be harnessed within an overarching sustainable transportation strategy. ISTEA provides the framework for such a strategy, but many issues must be addressed before ISTEA's vision becomes a reality. The following preliminary recommendations to the Minnesota ITS program—which subsequently will be refined and modified as the study proceeds—offer guidance to the Minnesota ITS program for incorporating principles of sustainability.

Specific program implications for Minnesota's ITS program are as follows:

1. *Explore the cost-feasibility/benefit of an emissions management system, of an aggressive pretrip information program, and of the potential for ITS to contribute to the effectiveness of demand-responsive transit.*

To date, much of the focus and public perception of ITS has been on increasing throughput on roads and highways. Yet ITS has the potential to serve many other goals and to provide a more balanced mix of modal options. Emissions management, pretrip traveler information, and demand-responsive transit are all areas in which ITS can support programs that promote sustainable communities. The emissions management function, for example, is conceived as a center subsystem (in the draft national ITS Systems Architecture) that could provide roadside information on emissions to inform the traffic management subsystems. Emissions management systems have been implemented elsewhere (e.g., Athens, Greece), and an evaluation of their appropriateness for Minnesota would be a natural follow-on to experimental testing that has already been conducted in the state.

2. *Consider the feasibility of one-stop shopping for travel and other information (deployed within downtown, suburban, and rural settings) within the broader context of other telecommunication services.*

An example of such one-stop shopping—an example that highlights the potential effects of the telecommunications revolution on

ITS and the provision of information about travel and related services—is the distance education opportunities and Department of Motor Vehicle information provided by the Los Angeles Transit Blue Line. This "bundling" of travel and related information can promote sustainability by making transportation more efficient, encouraging mode shifting, or reducing demand for travel. From a policy perspective, it makes sense to consider economies of scale for integrating ITS service provision with other forms of service provision.

3. *Adopt a multimodal, multiagency public outreach strategy to identify goals for ITS deployment, specifically within the context of community sustainability.*

Consultations with policy makers and community representatives in Minnesota revealed the importance of developing a process by which the communities themselves can play an active role in defining what they mean by sustainability. A clear message from these consultations, for example, was that participants believed that "a single-minded focus on moving cars undermines community livability." This has implications for ITS deployment in that it reveals the usefulness of involving community groups in the market research aspect of a project. The consultations also suggest that the concept of community sustainability should be treated in an iterative fashion. That is, while some aspects of it can be defined in the abstract, the process of involving community representatives can bring the concept to life for that community.

4. *To ensure that progress is made toward building more sustainable communities, it is critical that indicators of such progress be established.*

Indicators are "bits of information that highlight what is happening in the larger system. . . . Their purpose is to show us how well a system is working. They tell us which direction a critical aspect of our community, economy, or environment is going: forward or backward, increasing or decreasing, improving or deteriorating, or staying the same" (*18*). The authors have developed the following set of transportation-related indicators that could assist the Minnesota Department of Transportation and other transportation agencies in creating a transportation system that promotes sustainable communities:

- Car-to-transit ratio;
- Share of households within walking distance of transit;
- Average frequency of bus service;
- Ratio of sidewalk miles to street miles;
- Average travel time to work/school, shopping, and so on, by mode;
- Percentage of state and local budget devoted to transportation; and
- Green space–blacktop ratio.

5. *Seek a balance between demand-side and supply-side applications.*

Promoting sustainable communities through ITS will require increased analysis of the ways that demand for travel is affected by better information provision and by market incentives and disincentives that promote or discourage travel and mode shifting. One promising strategy in this regard is the introduction of high-occupancy toll (HOT) lanes as a form of congestion pricing, in which drivers pay a fee equivalent to the congestion delay that they impose on the transportation system. HOT lanes offer a new premium service of relatively congestion-free travel for those willing to pay or willing to travel by bus or carpool.

CONCLUSION

The authors end this paper on a cautionary note. Maximizing mobility—the movement of people and goods to and from destinations as quickly as possible—remains a critical concern among transportation planners and the public, and the promise of facilitating economic growth remains a powerful justification for emphasizing mobility as the primary goal of transportation policy. Moreover, transportation behavior has proven extremely difficult to change. Despite tremendous policy efforts to the contrary, automobile use continues to rise, transit use and carpooling continue to decline, and metropolitan areas continue to disperse. Any efforts to promote sustainable transportation must consider that "when it comes to cars, recalcitrant human nature has a way of wreaking havoc with planners' most high-minded intentions" (*19*). And finally, the politics of transportation pose a barrier to sustainability, as traditional highway lobbies and pork-barrel spending remain intregal parts of transportation's political landscape (*20*). The passage of ISTEA and the controversy over ITS illustrate the continuing struggle between fundamentally competing visions of which goals should guide transportation investments. Perhaps only this is certain: The road to sustainable communities, though certainly one worth choosing, is anything but a smooth ride.

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